19 [coat of arms] Patent Board
The Netherlands

11 Publication number: **9202158**

12 For **Filing and Viewing**

21 Application number 9202158

22 Filing date: 12/14/92

43 Filed:
01.07.94 I.E. 94/13

51. Int. Cl.^{5}
G06K 19/07, G06K 7/12,
H03E 3/06, H03D 7/00
H04L 27/18, H01Q 1/52

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54 **Identification system according to the transmission method**

An inductive identification system according to the full duplex principle, which according to the state of the art makes use of the absorption feature, whereby a resonating secondary LC circuit absorbs energy from a primary resonance circuit, can be improved by making use of a tertiary receiving antenna separated from the primary transmittal antenna, for the return route which is necessary for transmitting data of the identification label back to the requesting entity.

The items attached to this sheet are a copy of the originally submitted description with claim(s) and possible drawing(s).
NL A 9202158

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Identification system according to the transmission method

The invention involves a radio frequency identification system consisting of one or more labels, which can be read out from a distance by a readout device, a so-called transmitter/receiver, which for such purpose transmits a R(adio) F(requency) query signal, whereby, for obtaining a maximum detection distance, as well as a maximum chance for identification at passing a label at a fixed distance from the label path with respect to the transmission and receiving antenna(s), as well as a minimal interference sensitivity, the returned data signal is located in two narrow bands on each side of the query frequency and whereby a clear use is made of resonating by the resonance feature of the LC chain in the label, while said bands are located so far from the query frequency, that this latter frequency with sufficient band width can be filtered out upon reception, as well as the query signal of a nearby transmitter/receiver, for which the frequency may deviate somewhat, so that the latter does not interfere with the data signal received.

Said radio frequency identification systems are known from applicant's Dutch patent application No. 9201116.

Operation of such an identification system is illustrated in figure 1. The system consists of a readout device 1 and one or more detection labels 2. For querying identification label 2, querying field 3 is generated through transmitter 4. This field is radiated by spool 5. It involves a radio frequency magnetic field with a frequency of 120 kHz for instance. Spool 6 with resonance capacitor 7 in label 2 is adjusted to the frequency of querying field 3 and will resonate as a result of this field. With sufficient power over IC 8, it will operate; the label code is generated and is transmitted to code switch 9, which (partially) short-circuits resonance circuit 6,7 according to the rhythm of the code or data signal.

In the abovementioned patent application, it is further described how IC 8 is fed from the induced power over resonance circuit 6,7 and how a data block, stored in IC 8, is coded

as a base band signal in the form of a differential bi-phase, Manchester or Miller code. These three coding systems can be described as a special form of phase modulation (Eng: Phase Shift Keying, PSK) of a base band carrier wave. The essence hereof is that the data transfer in this base band signal takes place in a narrow frequency band around the frequency of this base band carrier wave, and that the lowest frequency band between zero Hz and the lower limit of said frequency band does not or hardly contains signal components, so that this lowest frequency band does not have to be transferred to the receiver.

In figure 2, the electric replacement diagram is shown for the abovementioned identification system according to the state of the art. It shows the fundamental operation. Transmitter connection 4 feeds antenna circuit 11. This circuit consists of a coil L1 (5), the loss resistor of coil R1 (12) and capacitor C1 (13). Current I1 through antenna coil L1 causes a magnetic field H1 (3). This is a magnetic alternating field with the frequency of the query signal, generated by transmitter connection 4. In magnetic alternating field H1 label 2 is found, with in it a LCR circuit 20 consisting of air or ferrite coil L2 (6), with its loss resistor R2 (21), and capacitor C2 (7). The self-induction values of coils L1 and L2 and the ratings of capacitors C1 and C2 are such, that the query antenna, as well as the label circuit are in resonance with the frequency of the query signal. The outgoing voltage V1 of transmitting connection Tx passes a current I1 in the serial antenna circuit 11, R1 (12), L1 (5) and C1 (13). Since the antenna circuit is in resonance, the imaginary impedances of L1 and C1 compensate each other, so that in the serial connection only the actual impedance of loss resistor R1 remains. As such, current I1 will be in phase with voltage V1. Also magnetic alternating field H1 (3), made up of current I1 passing through coil L1, will have the same phase as current I1 and with it, voltage V1. Alternating field H1 induces an induction voltage VL in coil L1 and also an induction voltage V2 in coil L2 of the label. These voltages are proportional with the changes in the magnetic flux passing through the related coils and as such run 90 degrees in phases behind current I1. Voltage Vc across capacitor C1, which is equal to the voltage across receiver connection Rx (17) is 90 degrees in phase behind current I1, so that the phase difference between voltages V1 and Vc is 90 degrees.

Figure 3 shows a vector diagram of the voltages and current, related to the electric replacement diagram of figure 2. Voltage V2 induced in the label coil causes a current I2 which, since this circuit is in resonance, is in phase with voltage V2, and as such is running 90 degree in phase behind current I1. In turn, current I2 through label coil L2 causes a secondary magnetic alternating field H2 (18). This alternating field, in phase with current I2, is as such running 90 degrees in phase behind the primary field H1 (3). Secondary field H2 induces in turn a voltage V3 in the primary coil L1, which voltage is then running 90 degrees in phase behind magnetic alternating field H2, as such behind voltage V2. Since V2 is running behind current I1, voltage V3 will run 180 degree behind current I1. Voltage V3 is as such positioned opposite voltage V1 at the outlet of transmitter connection Tx (4), and as such, reduces the amplitude of current I1. Seemingly, the loss resistance increases in value as the label is positioned in the query field. This means that the primary antenna circuit is dampened aditionally and that the extra loss is then in fact dissipated in loss resistor R3 of the label circuit. As such, the label circuit absorbs energy from primary antenna circuit 11.

This energy absorption is proportional to the secondary current I2, and as such inversely proportional with loss resistor R2 that is being determined by the Q factor of the label circuit. This means: the lower the loss of the label circuit, the higher the Q value, the smaller the loss resistance R2, the larger the current I2 at a constant V2 (depending on field strength amplitude H1), and the greater the energy absorption through the label circuit from the primary circuit. With a growing absorption, the amplitude of voltage V1 will diminish across C1, which can be recorded by receiver connection Rx (17).

As such, absorption can be adjusted by varying the losses in the label circuit, for instance, by adjusting serial resistor R2, or by connecting a parallel resistor in parallel to C2. In extreme cases, capacitor C2 is short-circuited through short-circuit switch 9 so that the label circuit no longer resonates, and a complete end is put to the energy absorption effect. By connecting switch 9 into the rhythm of the code signal, the code signal can now be transferred to receiver 17.

An identification system according to the operating principle described above is identified as being of the "absorption type".

Getting back the code signal in receiver 17 takes place in the identification system according to the state of the art using a diode rectifier, as is illustrated in figure 4. Diode D (24) shall conduct current Id, 27, if voltage Vc across capacitor C1 is more positive than voltage Vd across capacitor C4. This is illustrated in figure 5. Capacitor C4 is uploaded for each positive period half of the ac voltage Vc (with the frequency of the query signal) up to the maximum value of Vc (the amplitude value). For the period of time that Vc is smaller than Vd, load current Id is zero and C4 shall discharge through leakage resistor R4 (26). The voltage across C4 shall discharge progressively in between the peaks of voltage Vc, as is illustrated in figure 4. As long as the amplitude of Vc does not vary abruptly, C4 will always be charged again up to the peak value of Vc. The average value of voltage Vd is then giving a representation of the Vc amplitude, and as such of the absorption through the label circuit, and consequently of the code signal.

Closer examination of figure 4 makes it clear that the current Id through diode D, is only running for a short period for those short moments when Vc is greater than Vd. Only at the times that current Id is running, is diode D conducting and is there a conducting contact between C1, with antenna circuit 11, and C4. Therefore, one might also think of replacing diode D by a switch S2 (29), which is switched on and off synchronous with the query signal. Command of the switch can in principle be generated separately at another location in the connection of the transmitter, but can be imagined as the analog of the diode detector of figure 4, in which the switch is closed by voltage Vc above a certain threshold value, to be determined by a threshold detector 30. In the special case that the threshold detection consists of the comparison of Vc with Vd, the connection of figure 6 has become exactly equivalent to that of figure 4.

From the trades involved in instrumental electronics and radio communication technology, it is known that with the help of a repeating on/off switch, a so-called

multiplying mixer circuit can be achieved. This is a circuit for which the outgoing signal is the mathematical product of the two incoming signals. In the case of a switch, the one incoming signal is a square wave with frequency equal to the switching frequencies of that switch. In the frequency domain, multiplication of two signals provides new spectral components of which the frequencies are the sum and the difference of the frequencies of the original signals.

The above applied to switch S1 in the label circuit means that the query signal, induced in label circuit 20, is one incoming signal, having for instance a frequency of 120 kHz, and the code signal that is generated by IC 8 and serves the switch, is the second incoming signal.

In figure 7, frequency ranges are illustrated. In figure 7a, base band carrier wave fc is illustrated on the left, for instance with a frequency of 1875 Hz, identified by 50, with on both sides frequency band 51, that are covering the modulation products, after the base band carrier wave is modulated with the NRZ code or data signal. This modulated signal with frequency band 51 is further identified as the base band signal. This signal commands switch S1, which, in the closed position, dampens label circuit 20 (see figure 2). Query signal fi induced in the label circuit, for instance with a frequency of 120 kHz, is multiplied with the base band signal. In figure 7a, the query signal is identified with 52.

Figure 7b shows the product signals. Using the base band carrier wave frequency, in this example being 1875 Hz, now the subsequent signal path can be described. Multiplication of query signal fi with base band carrier wave fc, which hereinafter is called frequency conversion in accordance with the trade terminology used, provides a so-called sum signal, of which the frequency is the sum of the incoming signals, as such fc' = fi + fc, in this example, 120 kHz + 1875 Hz = 121.875 kHz, and a difference signal: fc" = fi – fc, or 120 kHz – 1875 Hz = 118.125 kHz.

Traditionally, the signal with the highest frequency band is called the upper side band signal (USB) and the signal with the lowest frequency band, the lower side band signal

(LSB). These signals are shown in figure 7b. Here it must be pointed out that the LSB signal with respect to the query frequency fi, is the mirror image of the USB signal.

This process of converting signal frequencies, but while preserving the informative and energetic contents, is called frequency conversion.

The USB and LSB signals fall within resonance curve 53 of label circuit 20 as well as of the transmitter/receiver circuit 11. This means that both signals produce resonating circuit currents in label circuit 20, as extra component of I2, as well as through the induction coupling in transmitter/receiver circuit 11 as component of I1. Figure 7c shows these signals in the transmitter/receiver circuit. Also there query signal fi is shown.

Switch S2, in this case the diode connection of figure 4, again produces a multiplication and frequency conversion process for the signals, present in transmitter/receiver circuit 12. This produces three difference and three sum signals, namely:

1. The USB signal produces again a difference with query frequency fi that is a base band signal as originally in figure 7a, in other words, fc' – fi = fc.
   In the example: 121.875 kHz – 120 kHz = 1875 kHz.
2. The LSB signal produces again a difference with query frequency fi that is the same base band signal, namely: fi – fc" = fc. In this example: 120 kHz – 118.125 kHz = 1875 kHz. This is again a mirror image with respect to the query frequency.
3. The query signal present in the circuit gives a difference of: fi – fi = 0 Hz. As such, this is a dc voltage, which can easily be filtered from the circuits that follow this detector, even when this signal is very strong in comparison with the label signals.
4. The three sum signals: fi + fc', fi + fc" and fi + fi are all positioned in the frequency range around 2 x fi, in the example: 2 x 120 kHz = 240 kHz, and are easily filtered out by capacitor C4 and by simple low pass filter circuits, included in the circuits that come after this detector. They are not shown in figure 7d and their effects can be otherwise ignored.

Multiplying mixer switching as described above, and intended to convert the radio frequency signals downward towards the base band signals, is further also indicated as a product detector. From the already mentioned trades, it is known that the diode detector in this application, in which a very strong query signal of about 200 Volt is present, together with a much weaker label signal and possibly other signals, behaves like a perfect product detector, this means, a connection for which the outgoing signal consists exclusively of mathematical products of the strong signal (the query signal) with the incoming signals.

It must be pointed out that the frequency conversion of the USB signal as well as the LSB signal produces two identical base band signals. These two base band signals are added as voltages, and that produces a signal amplification of 6 dB. The noise components, present in the frequency bands of the USB and LSB signal, and which are also converted towards the same base band, are also added. But since the noise components are not mutually correlated, an addition of power ranges will take place, so that the total noise base band signal only increases by 3 dB.

Consequently, the net result of the combination of the USB and the LSB label signal is a gain in signal/noise ratio of 6 -3 = 3 dB.

Of practical importance is the situation in which a second transmitter/receiver is connected nearby the first one, so that its query signal induces a circuit current in transmitter/receiver circuit 11 of the first transmitter/receiver. Due to the large dimensions of the transmission/receiving coil with respect to the label coil, this second transmitter/receiver can, at a considerable distance, already cause a signal level in the first transmitter/receiver that is comparable with the signal level of the USB and LSB signals of the label, and as such form a potential interference source when receiving the label signal. Through production tolerances, the query frequency fi'of the second transmitter/receiver can deviate somewhat from query frequency fi of the first. In the example given, this difference can be up to 100 Hz. In figure 7c, fi' is shown as being

somewhat higher than fi. After the frequency conversion, the resulting difference signal is a base band product fi" with a frequency that lies far outside frequency band 51, in the example, smaller than 100 Hz. Likewise, if fi' had been somewhat below fi, this would also have produced a base band product with the same frequency.

Through a simple high pass filter in the circuits following this detector, fi" can be removed effectively, so that it becomes possible to use several transmitters/receivers next to each other without any interference from each other, or without synchronization of the query signals being necessary.

Another practical aspect is that the signals received by the transmission/receiving coil from the radio transmitters, that are also transmitting in this frequency range, such as for instance the Offenbach weather map fax sender at the 132 kHz frequency, are also converted to the base band. For the example, the frequency difference is then 132 – 120 = 12 kHz. These frequencies are shown in figure 7.c and 7.d as fcom, and fcom' respectively. It is also clear that the base band product lies far outside frequency band 51 of the label signal, and as such, can be easily removed with a low pass filter.

From the above, it becomes clear how the further makeup of the receiver has to take place. Figure 8 shows the elementary block diagram. Here, 40 is the already discussed diode detector, 41 is the high pass filter, that has to remove all interference signals, that are lower in frequency than frequency band 51 of the label base band signal. Block 42 houses a low pass filter that must filter out all interference signals in the base band with frequencies above that of the label signal. Together, 41 and 42 form a pass band filter that only lets pass frequency band 51 of the label base band signal. In the example, this runs from 500 to 2500 Hz.

After the filters only follows the amplifier that brings the signal to such a level, so that demodulation of the PSK modulated base band signal is possible, so that the NRZ coded data signal becomes available again. It is essential that the amplifier is preceded by filters

41 and 42. Only then is an effective elimination of interference signals possible without affecting the desired signal.

Such a receiver setup, together with a product detector at the inlet of the receiver, which transforms the received radio frequency signal in one step to the base band, is called a direct conversion or homodyne receiver. In this application, in which the direct conversion receiver receives a double side band signal, the combination of the USB and LSB signals correlated to each other, and in which the conversion signal is synchronized with the query signal with which the double sideband signal is generated, the receiving principle is identified with synchronous direct conversion.

The basic advantages of a direct conversion receiver are that receiver selectivity is determined by a relatively simple filter connection to the low frequency of the base band. This contrary to the more traditional receiver designs, such as for instance the often applied super heterodyne receiver, in which the received radio frequency signal in a frequency conversion process is first converted into a so-called Intermediate Frequency (IF), often with a frequency of 455 kHz or 10.7 MHz. To obtain the same selectivity, filters must be put in place at this intermediate frequency, which, in an absolute sense have to have the same band width as in the direct conversion setup; however, due to the high frequency, they require a much smaller relative band width. As a result, such filters are much more difficult to design and to produce. Furthermore, there is in essence the given that the query signal itself can be filtered out in a very simple fashion, because after a frequency conversion it provides a dc voltage. For the super heterodyne solution, this is very difficult to achieve. It would require a very sharp suppression filter or notch filter and it is almost impossible to achieve reliably due to the requirements of this application.

As such, the synchronous direct conversion principle is par excellence suitable to be used with identification systems where simultaneously a query signal is sent out and a code signal of a label must be received back, the so-called Full Duplex Identification Systems. The identification system herein described according to the present state of the art, and the identification system to be described according to the invention, are examples thereof.

A disadvantage of the identification system described herein according to the absorption type is as follows. The query signal is generated in a transmitter connection. This produces noise components that become a part of the query signal. The level of these noise components is low; for instance, -144 dBc/Hz at 1 kHz from the query frequency and -147 dBc/Hz at a distance of 2 kHz. For this label to operate, this noise has no effect but upon receiving the label signal, these noise signals are also present in the transmission/receiving circuit. As such, this noise is mixed with the label code signal, is also converted downward in frequency to the base band, and is ultimately passed by filters 41 and 42 in the base band frequency range 51 of the label signal, and ultimately, it may prevent the proper demodulation of the data signal.

This means that in practice, the noise level of the transmitter connection sets the boundary for receiver sensitivity.

Though the detection sensitivity for the identification system described above according to the absorption principle is sufficient for portable readout devices, the purpose of the invention is to provide such a combination of transmitter, receiver and antenna coils, that a greater receiver sensitivity can be obtained, which can lead to larger identification distances, or greater identification accuracy, in particular, with stationary readout units.

The starting point for the invention is that the receiving inlet is not directly coupled to the combined transmitting/receiving antenna coil, but is coupled either to its own receiving antenna coil, that has such a form or is set up in such a way with respect to the transmitting antenna coil, that the direct coupling between the transmitting antenna coil and the receiving antenna coil is reduced, or is coupled through a coupling circuit, duplexer circuit or directional coupling circuit to a common transmitting/receiving antenna coil, so that the receiver receives the query signal only in weakened form.

In particular, the invention is related to the abovementioned solution with a separate receiving antenna.

In figure 9, the electric replacement diagram is shown. Transmitting circuit 11 is illustrated herein as transmitting/receiving circuit 11 in figure 2, as well as label circuit 20. In addition, a separate receiving circuit 30 is illustrated, consisting of a receiving antenna coil L3, represented by 31, its electric loss resistor R3, represented by 33, capacitor C3, represented by 32. This circuit is again connected to receiver connection 34. The receiver is also connected to the transmitter to pass through a reference signal for the product detector in the receiver connection (through connection 35).

Like in the identification systems according to the state of the art, as described above, transmitter 11 generates a magnetic alternating field H1, shown as 19, that is in phase with current I1 through transmitting coil L1. Induction voltage V2 generated by field H1 in label coil L2 will again produce a secondary current I2 which causes again a secondary magnetic alternating field H2, shown as 18. Also this magnetic field is in phase 90 degrees behind the primary field, since induction voltage V2 runs 90 degrees behind field H1, and because the label circuit is in resonance , the circuit current will be in phase with induction voltage V2.

In receiving antenna coil L3, now two induction voltages are generated, namely V3, represented by 36, that is caused by secondary field H2 and as such runs 90 degrees in phase behind the field, and V4, represented by 37, that is generated by primary field H1, and as such runs 90 degrees in phase behind filed H1. But the phases of the primary and the secondary field were 90 degrees out of phase, so that also induction voltage V3 will run 90 degrees behind V4. The receiving antenna circuit 30 is also in resonance with the frequency of the query signal. Consequently, as a result of the induction voltages, circuit currents I3, I4 will run in phase with the respective induction voltages V3 and V4. As such, voltages are generated across capacitor C3, represented by 32, which run 90 degrees behind the circuit currents that they are causing. It is essential however, that the phase difference between the voltage across C3, and consequently at the receiver incoming terminals, caused by the secondary field and the voltage generated by the

primary field, is 90 degrees and is independent from the features of receiving antenna circuit 30.

Observation of the 90 degree phase differential between the signal received from the label, and that signal (the query signal) that is received directly from the transmitter, is the essence of the invention.

Figure 10 shows a phase diagram of voltages V3 and V4. Voltage V4 created by the direct coupling is very dominant with respect to label signal V3. This means that voltage V3 has little effect on the amplitude of the resulting voltage Vr. Detection on the total signal Vr, that is offered to the receiver incoming terminals, for instance with the diode detector of figure 4, will as such result in little sensitivity. Therefore, it does not make sense to select a receiver type of the classical type such as the heterodyne type or the straight type, since, inevitably, these receive the resulting signal Vr and amplify it as a whole.

However, the receiver type of the synchronous direct conversion is applicable. Figure 11 is showing its elementary block diagram. In this receiver, the antenna signal is given to product detector 45. The product detector also receives a reference signal, coming from the transmitter, and which in phase changer network 46 is shifted in phase in such a way that this reference signal and the received label signal have the same phase. Mathematically it can be quickly derived that in this situation of equal phase, the product detector gives a maximum output. Just as the phase difference between the incoming signal and the reference signal is 90 degrees, the output of the product detector is zero. That is the case for the direct coupled query signal, including the noise that is part of the query signal. At the same time, as a result of the label signal, the output is dependent on the level of the direct coupled query signal. The product detector, that also functions as frequency converter, equal to the diode detector connection in the identification system according to the absorption principle, converts both side band components of the label signal to the base band, as is described also for the diode and the connection detector.

The product detector is mostly executed as a so-called double balanced mixer circuit. These circuits can be obtained in the passive form, as well as in the active form, the latter mostly as an integrated circuit. They consist of four connection components that are classified in such a way that the incoming signal itself as well as the reference (connection) signal do not appear at the outlet.

This receiver also consists of the same parts as the earlier described receiver in the identification system according to the present state of the art and it also operates in an identical manner.

An identification system according to the invention described in this document, is shown with the "transmission type".

The advantage of an identification system according to the transmission principle lies in the fact that the noise of the query signal enters much weaker in the receiver as a result of:

1. the weak coupling between the transmission antenna coil and the receiving antenna coil;
2. the insensitivity of the phase synchronous detection at the receiving inlet for the direct coupled signal.
   As such, the sensitivity is no longer determined by this transmitter noise, and the receiver can be considerably more sensitive. When that is combined with a stronger query signal, the identification distance can be considerably increased in comparison with what is possible with an absorption identification unit. This greater identification sensitivity can also be converted in a larger identification reliability in applications for traveling band systems for instance.

CLAIMS

1. Radio frequency identification system consisting of one or more labels which can be read out from a distance, such as for instance described in patent request No. 920116 of applicant, with the feature that said label is at the same time inductively coupled with a transmission antenna coil, which generates a magnetic query alternating field, and with a receiving antenna coil, which couples the radio frequency code signal generated by the label to a receiver.

2. Radio frequency identification system according to claim 1, characterized by the fact that both transmission and receiving antenna coils are set up among each other in such a way that the query magnetic alternating field couples partially or absolutely not, with the receiving antenna coil.

3. Radio frequency identification system according to claim 1, characterized by the fact that the transmission antenna coil and/or the receiving antenna coil is/are of such a form that, through the coupling of the receiving antenna coil with the induction voltage generated by the query field, is compensated in full or in part.

4. Radio frequency identification system according to one or more of claims 1 through 3, characterized by the fact that the receiving antenna coil is coupled to a product detector, in which the signals, induced in the receiving antenna coil, are multiplied with a reference signal, having the same frequency as that of the query signal, or with a multiple or sub-multiple thereof.

5. Radio frequency identification systems according to claim 6, characterized by the fact that the reference signal has such a phase with respect to the query signal, that the output signal of the product detector as a result of the query signal, including the noise components transmitted with the query signal, is minimal, while at the same time, the output signal is maximal as a result of the label code signal.

6. Radio frequency identification system consisting of one or more labels which can be read out at a distance such as for instance according to applicant's patent application 9201116, characterized by the fact that said label is coupled inductively with a transmission/receiving antenna coil, and which coil is connected with a transmitter and receiver circuit through a coupling circuit, duplexer circuit or directional coupling circuit, so that the direct coupling between the transmitter and the receiver is minimal, while at the same time, the coupling between the transmission/receiving antenna coil and the receiver circuit is optimal.

7. Radio frequency identification system according to claim 6, characterized by the fact that the receiving antenna coil is coupled through one of the coupling circuits from claim 6 to a product detector, in which the signals, induced in the receiving antenna coil, are multiplied with a reference signal, having the same frequency as that of the query signal, or with a multiple or sub-multiple thereof.

8. Radio frequency identification systems according to claim 7, characterized by the fact that the reference signal has such a phase with respect to the query signal that the output signal of the product detector as a result of the query signal, including the noise component sent with the query signal, is minimal, while at the same time, the output code as a result of the label code signal is maximal.